RT-IDA3D: Towards a Real-Time Computerized Ionospheric Tomography System Suitable as Input to Ionospheric Data Assimilation Models

Dr. Gary S. Bust
Applied Research Laboratories, The University of Texas at Austin
10000 Burnet Austin, Texas 78758
phone: (512) 835-3623 fax: (512) 835-3808 email: gbust@arlut.utexas.edu

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LONG-TERM GOALS

1. Develop a global, multi-sensor, real-time electron density specification algorithm (RT-IDA3D),

2. Host RT-IDA3D on a Beowulf parallel computing environment,

3. Provide an interface from RT-IDA3D to operational ionospheric data assimilation models developed under the MURI program,

4. Incorporate RT-IDA3D into Navy applications that require ionospheric specification, and

5. Carry out scientific investigations of the ionosphere with RT-IDA3D

OBJECTIVES

The main objectives of this project are to 1) add new data sources to the existing IDA3D algorithm, including GPS occultation data, EUV limb-scan data, and DMSP in-situ data; 2) port the existing IDL code to FORTRAN-90 and get it running on the ARL:UT test beowulf cluster; 3) make the algorithm truly global with an irregular adaptive grid; 4) add a predictive model option for the background model; and 5) make it real-time.

APPROACH

The approach is a 3 phase approach, over three years. The first phase consists of adding data sources and making the algorithm global with an irregular grid. The second phase consists of completing the port to FORTRAN-90, adding the predictive model input and hosting it on the Beowulf cluster. The third phase focuses on the real-time aspects and the interfaces to data assimilative models and other Navy applications.

WORK COMPLETED

Currently, phase one is complete. The algorithm is global and uses an irregular horizontal grid that adapts to data density. All data sources have been added, and most have been tested under actual data collect situations.

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14. ABSTRACT

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RESULTS

IDA3D has been used to investigate the high-latitude ionosphere extensively in the last year, resulting in several presentations at scientific conferences, a new NSF patch study, and an investigation of a space weather, transient magnetospheric-ionospheric coupling event that is discussed in detail below.

As part of an investigation of high-latitude variability, IDA3D was run for December 12, 2001, with an electron density specification obtained every 15 minutes. Upon detailed analysis of the results, an interesting magnetospheric-ionospheric coupling event was observed at ~05:40 UT, in the 3 MLT region of the ionosphere. The data sources available as input to IDA3D for this event include ~300 GPS TEC data points, 4 CIDR receivers in Greenland and 2 ionosondes. From the 3D electron density map, vertical TEC (VTEC) was obtained, as well as a 2D slice along the tomography pass 350 km intercept track. Some of the observations obtained from this analysis include (see Figures 1 and 2):

- A steep depletion in VTEC (< 3 TECU) at ~73 geomagnetic latitude and ~22° longitude
- The 2D slice shows that density is < 10^{11} el/m^2 in the depletion region and roughly field aligned
- Density is depleted on both on bottom side F region and Topside

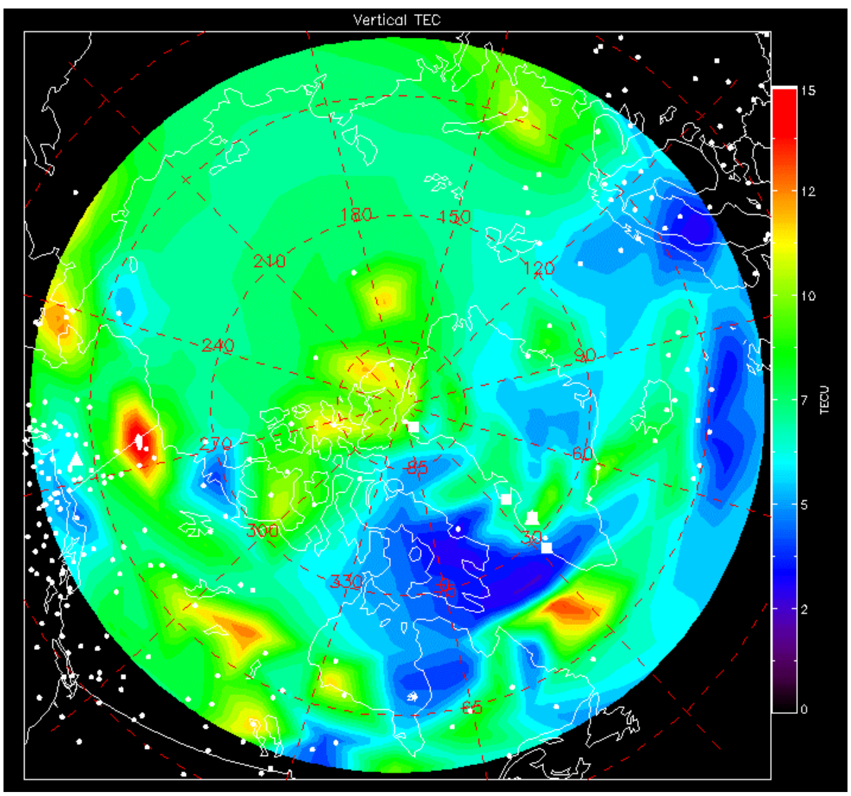

Figure 1: Vertical TEC at 05:40UT from IDA3D. The depletion region is just southwest of Greenland.

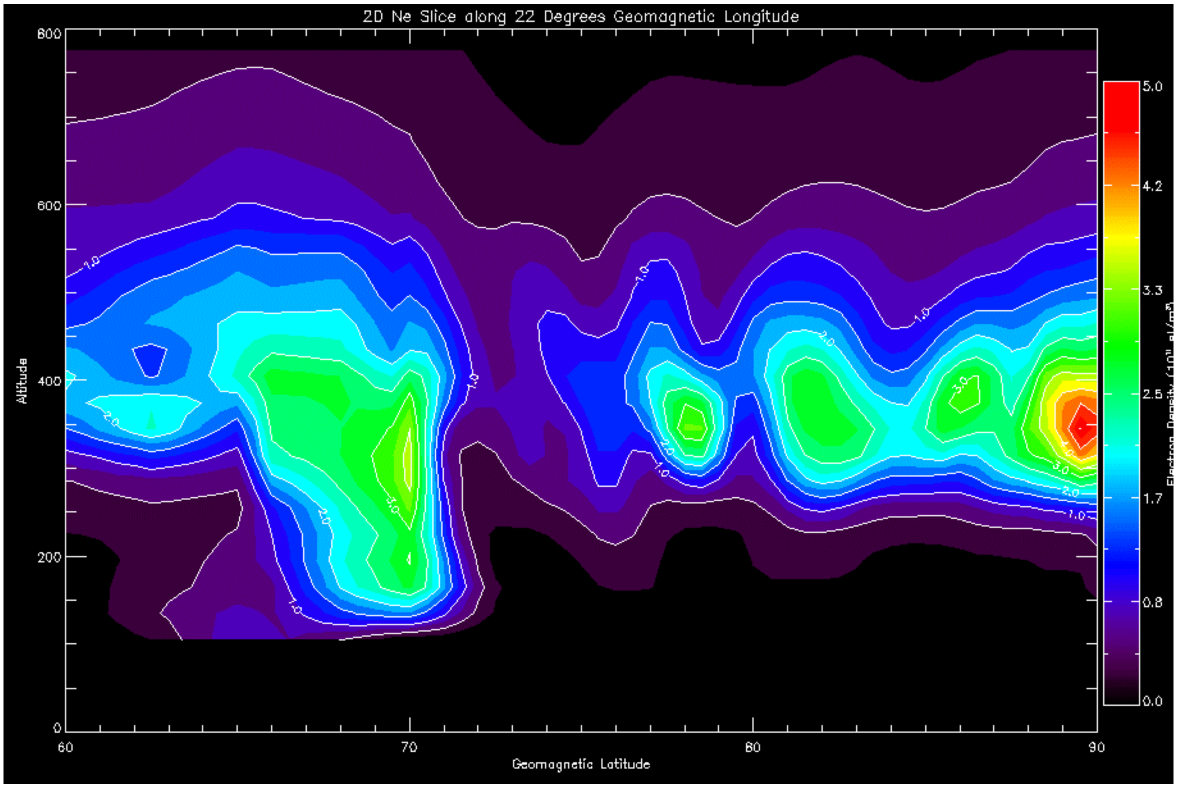

Figure 2: 2D slice along Satellite Track. Depletion region is < 1.0 x 10^{11} e^{-}/m^{3}

Figure 3 shows a SuperDARN convection map for the same time period as the IDA3D reconstruction. The large convection vortex lasts for < 30 minutes duration. The IDA3D electron density results can be used to obtain integrated conductances throughout the region. The IDA3D derived conductances can be combined with the SuperDARN convection to obtain the pederson and hall currents. Finally, the divergence of the Pederson and hall currents gives the current parallel to the magnetic field. Figure 4 shows the IDA3D derived pederson conductance, while Figures 5 and 6 show the pederson current and parallel current respectively. In addition to the IDA3D and SuperDARN results, approximately 1 hour earlier, the ACE satellite observed rapid fluctuations in the solar magnetic field – particularly the B_y and B_z components. Possibly, such dynamic fluctuations generated a current or field fluctuation in the post-midnight magnetosphere tail region (downward region 1 currents).

One possible interpretation of these results is the following:

- Short time, dynamic change in IMF - particularly B_y, produces field aligned current in the magnetotail - morning sector ~ 3 MLT.

- Due to the fact that at ~73 degrees latitude 3 MLT is in the polar hole there is almost no electron density -> no conductivity -> current cannot flow in ionosphere. Thus large electric fields build up around the depletion: poleward north of depletion, equatorward south.

- The large convections produce a positive feedback through larger ion temperatures, increased recombination, which lowers the conductance even more -> increase in E (convection).

- Meanwhile, at a slower rate, more diffusely, electrons are precipitating along Region 2 field aligned paths, and increasing conductivity equatorwards of the main positive current source (in Morning sector)

- Eventually, the conductivity is large enough, horizontal currents can flow from Region 1 at ~72° geomagnetic latitude to Region 2 at ~66°.

- Now large current flow -> large E fields for a short time, and then the system "drains itself"

IMPACT/APPLICATIONS

Potential impact of a global near real-time 4D specification of electron density can be enormous. Estimates of conductances, space-weather maps, HF and transionospheric propagation can all be important and applications that require ionospheric specification can benefit.

TRANSITIONS

Current transitions include applying IDA3D to a current DoD funded national asset program, coupling IDA3D estimated conductances to the magnetospheric Rice Convection Model and using IDA3D results to predict HF propagation from HAARP.

RELATED PROJECTS

- HAARP – Wink Radar propagation studies

- NSF patch study

- DoD national asset program

REFERENCES

Bust, G. S., C. Coker, D. Coco, T. L. Gaussiran II, and T. Lauderdale, IRI Data Ingestion and Ionospheric Tomography, 27(1), Adv. Space Res, 2001

Bust, G. S., D. Coco and J. Makela, Combined Ionospheric Campaign 1: Ionospheric Tomography and GPS total electron count (TEC) Depletions, 27(18), Geophys. Res. Lett., 2000

Bernhardt, P.A., R.P. McCoy, K.F. Dymond, J.M. Picone, R.R. Meier, F. Kamalabadi, D.M. Cotton, S. Charkrabarti, T.A. Cook, J.S. Vickers, A.W. Stephan, L. Kersley, S.E. Pryse, I.K. Walker, C.N. Mitchell, P.R. Strauss, Helen Na, C. Biswas, G.S. Bust, G.R. Kronschnabl and T.D. Raymund, Two-dimensional mapping of the plasma density in the upper atmosphere with computerized ionospheric tomography (CIT), Physics of Plasmas, 5(5),1998

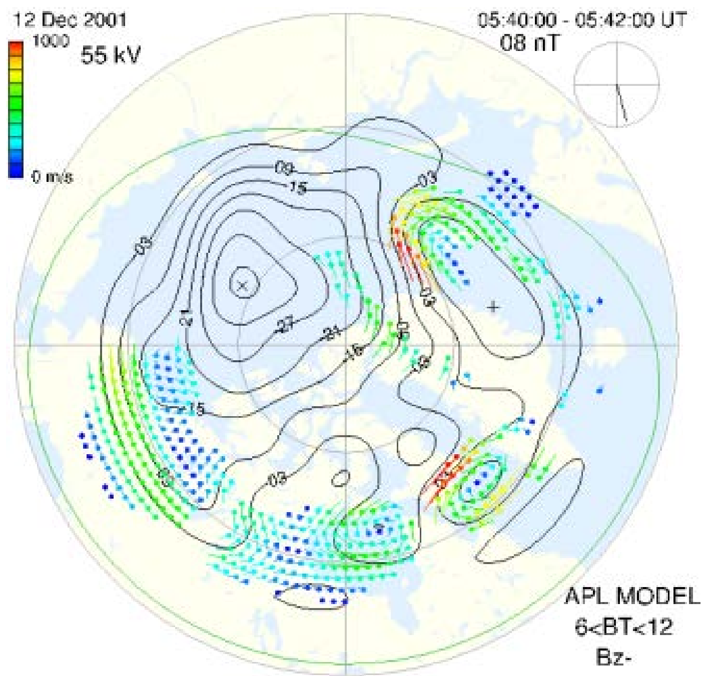

Figure 3: SuperDARN convection pattern. Note the large counter-clockwise vortex in the same region as the depletion.

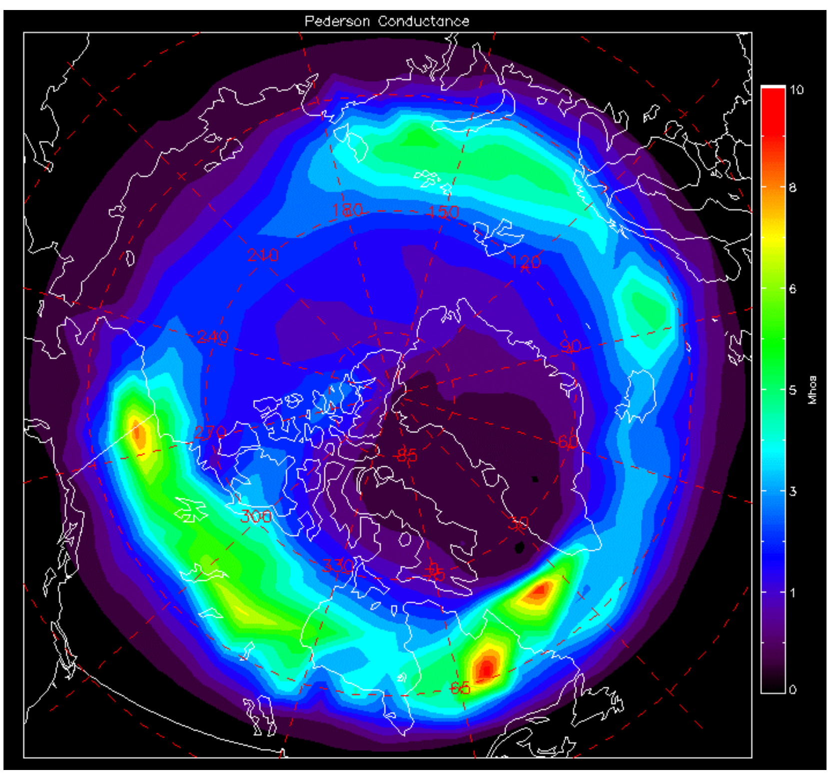

Figure 4: Pederson conductance. Note large conductance south of depletion region.

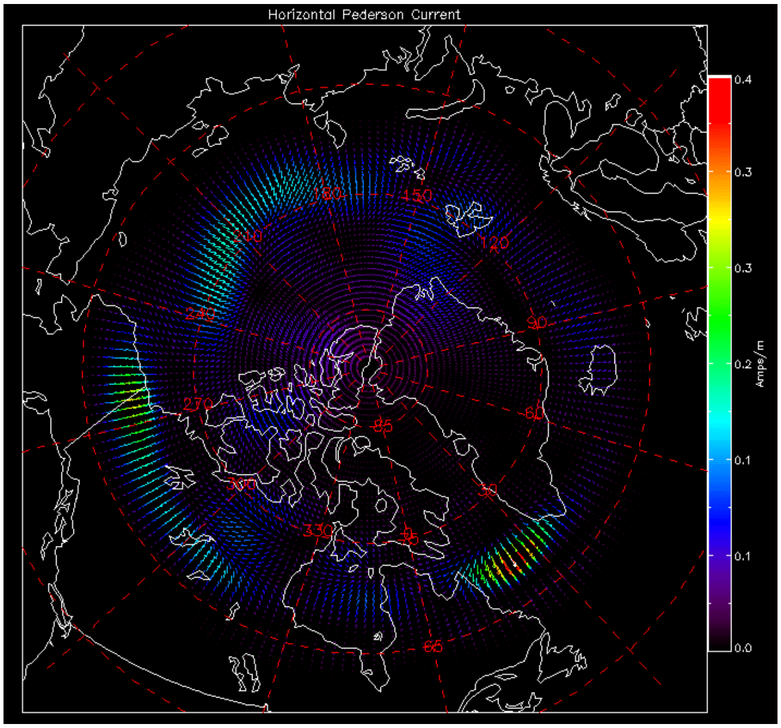

Figure 5: Derived pederson current, with a large (~0.4 A/m) southward current just below the depletion region.

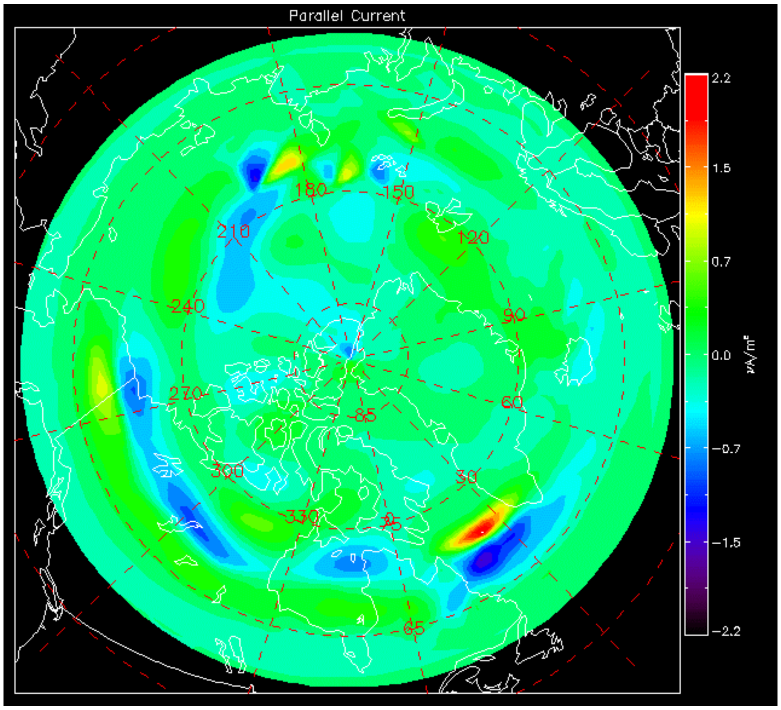

Figure 6: Parallel current. Note the enhanced (~ 2.2 $\mu A/m^2$) downward (region 1) current at ~72 degrees latitude and the weaker more diffuse (~ 1.5 $\mu A/m^2$) upward current (region 2) at ~68 degrees.

D. Knipp, G. Crowley, B.A. Emery, T. J. Fuller-Rowell, G. Hoogeveen, A. Jacobson, M.J. Buonsanto, S. Maurits, G. Bust, P. G. Richards, R. Clark, J. R. Taylor, M. Codrescu, B. J. Watkins, Recent results of the CEDAR Storm Study, Adv. Space Res., 20(9),1997

Bust, G. S., T. L. Gaussiran II, and D. S. Coco, Ionospheric observations of the November 1993 storm, J. Geophys. Res., 102, 14, 293-304, 1997

G. S. Bust, J. A. Cook, G. R. Kronschnabl ,C. J. Vasicek, and S. B. Ward, “Application of Ionospheric Tomography to Single-Site Location Range Estimation”, J. Img. Sys. Tech., Vol 5, 1994

Roger Daley, Atmospheric Data Analysis, Cambridge Atmospheric and Space Science Series, Cambridge University Press, Cambridge

PUBLICATIONS

Watermann, J., G. S. Bust, J. P. Thayer, T. Neubert and C. Coker, Mapping plasma structures in the high-latitude ionosphere using beacon satellite, incoherent scatter radar and ground-based magnetometer observations, 45(1), Annals of Geophysics, 2002

Bernhardt, P.A., J.D. Huba, C.A. Selcher, K.F. Dymond, G.R. Carruthers, G. Bust, C. Rocken, T.L. Beach, New Systems for Space Based Monitoring of Ionospheric Irregularities and Radio Wave Scintillations, Space Weather, Geophysical Monograph 125, AGU, 2001

Bust, G.S., D.S. Coco and T.L. Gaussiran II, Computerized Ionospheric Tomography Analysis of the Combined Ionospheric Campaign, 36(6), Radio Science, 2001

Coker, C., G. Kronschnabl, D.S. Coco, G.S. Bust and T.L. Gaussiran II, Verification of ionospheric sensors, 36(6), Radio Science, 2001

PATENTS

None.